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TECHNICAL TRANSLATION

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MAGNESIUM AND CALCIUM IONS IN THE EARTH'S UPPER ATMOSPHERE

By V. G. Istomin

Translation of "Iony Magniya i Kal'tsiya v Verkhney Atmosfere Zemli." Doklady Akademii Nauk SSSR, T. 136, No. 5, Feb. 11, 1961.

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MAGNESIUM AND CALCIUM IONS IN THE EARTH'S UPPER ATMOSPHERE*

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Sodium was detected in the upper atmosphere more than twenty years ago (ref. 1). Its presence was established and confirmed by the presence of D lines in the twilight- and night-sky luminescence spectrum. During recent years, lithium- and ionized-calcium lines have also been detected in the twilight-sky spectra more than once (refs. 2 and 3). The presence of metals other than these has not, so far as is known, been observed in the atmosphere.

Because most of the twilight- and night-sky luminescence investigations are carried out from the earth's surface, data about the emission heights and the extension of luminescent layers and their profiles, which are essential for the understanding of conditions in the upper atmosphere layers, are obtained with a rather high degree of uncertainty. Neither can the estimate of metal atoms concentration, which is made in the course of such type of measurements, be considered absolutely reliable.

The estimate is determined in an indirect manner, and its magnitude is essentially dependent upon a series of not very reliably determinable factors. It is natural that owing to the above-described causes, a direct detection and measurement of atoms (ion) of alkaline and alkaline-earth metals in the upper earth's atmosphere should be of interest.

During the launching of a geophysical rocket on the morning of June 15, 1960, in the middle latitudes of the European SSSR, an ion radio-frequency mass spectrometer recorded magnesium Mg^+ and calcium Ca^+ ions, together with the usual positive nitrogen oxide NO^+ ions and molecular oxygen O_2^+. The mass spectrometer was installed in a separable container which assured the conducting of measurements in the atmosphere region uncontaminated by the rocket. This method is in every respect similar to that previously described in reference 4, the only difference being that the mass spectrometer used on this occasion was several times more sensitive than the one used in reference 4.

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*Translation of "Iony Magniya i Kal'tsiya v Verkhney Atmosfere Zemli." Doklady Akademii Nauk SSSR, T. 136, No. 5, Feb. 11, 1961, pp. 1066-1068.

Slightly more than 100 spectra were obtained at altitudes from 92 to 206 kilometers, five of which had peaks with 24 to 26 mass numbers. Among these spectra three were obtained in the ascending branch of the trajectory, and two were obtained in the descending one. These and also the several preceding and following spectra are reproduced in figure 1. Attention is called to the good correspondence of peak-recording altitude with $M = 24$ and $M = 26$ on the ascending and descending branches. Thus are obtained spectra with the maximum amplitude of these peaks at altitudes from 103.5 to 105 kilometers. Taking into account the fact that the period of deployment along masses was equal to approximately 3 seconds, which in the given case is equivalent to a change of altitude of approximately 4 kilometers, such altitude coincidence is more than satisfactory.

The element having a mass number $M = 24$ is magnesium. Aside from the Mg^{24} isotope, there also exist Mg^{25} and Mg^{26} isotopes, their relative abundance being, respectively, 78.6, 10.1, and 11.3 percent (ref. 5).

If the recorded ions with $M = 24$ and $M = 26$ are magnesium ions, the relation of amplitude peaks $\frac{i_{24}}{i_{26}}$ must be equal to 7.

The results of peak-amplitude measurements of the spectra are given in table 1.

Taking into account the possible systematic errors, the obtained average value $\frac{i_{Mg^{24}}}{i_{Mg^{26}}} = 9.3 \pm 5$ must be recognized as confirming the proposed identification of the ions with $M = 24$ and $M = 26$ with magnesium ions. The Mg^{25} isotope is not visible because of insufficient resolution (clearance), but a certain dissymmetry of the base of the Mg^{24} peak indicates its presence (spectrum for $T = 123$ sec).

The maximum value of the relative intensity of magnesium-ion peaks in relation to the aggregate intensity of all recorded ionospheric components is:

$$\frac{i_{Mg^+}}{\left(i_{NO^+} + i_{O_2^+} + i_{Mg^+}\right)} = 0.17$$

The electron concentration in the given launching was measured by means of an ultrashort wave dispersion interferometer, similar to the one described in reference 6. At altitudes from 100 to 110 kilometers $n_e \simeq 8 \times 10^4$ cm^{-3}, wherefrom the value of the maximum concentration of magnesium ions at altitudes from 103.5 to 105 kilometers will be $n_{Mg^+} = 1.36 \times 10^4$ cm^{-3}.

Figure 2 shows the data obtained for the variation of magnesium-ion concentration with altitude, and the possible profile of the larger layer is plotted. Estimating the halfwidth of the layer equal to 5 kilometers, the whole number of ions in the column of the unit section $N_{Mg^+} \cong 7 \times 10^9$ cm^{-2}.

By an attentive study of the spectrum for $T = 123$ sec (fig. 1), obtained over its ascending branch at an altitude of 103.5 kilometers, a very noticeable peak with $M = 40$ can be observed. Since there is definitely no $M = 40$ peak in the preceding and subsequent spectra, it is natural to link its recording with a simultaneous appearance of Mg^+ ions and to ascribe it to the presence of Ca^+ in the same layer. (The relative abundance of Ca^{40} isotopes is 97 percent.) Because of the fact that the lines of ionized calcium CaII are present in the luminescent twilight-sky spectra (refs. 2 and 3), the identification of ions with $M = 40$ with Ca^+ ions cannot be questioned. The Ca^+ ion peak is not detected by means of other spectra of figure 1, since its intensity is lower than the maximum detectable.

The recorded ratio of magnesium- and calcium-ion concentration is $\frac{n_{Mg^+}}{n_{Ca^+}} = 25 \pm 8$ and the calcium-ion concentration is $n_{Ca^+} \cong 540$ cm^{-3}.

Taking the profile of the layer for Ca^+ ions to be the same as that for Mg^+ ions, we have the result that the whole number of Ca^+ ions in the unit section column is $N_{Ca^+} \cong 3 \times 10^8$ cm^{-2}. This magnitude is close to the estimate made by means of observation of the twilight-sky luminescence lines CaII, set forth in reference 3 as: $N_{Ca^+} \cong 5 \times 10^8$ cm^{-2}. The latter results are entirely juxtaposable with the described data obtained in the same month (June), during the diurnal meteor-shower activity of Arietid and Perseid (ref. 7). It must also be pointed out that there is good correspondence between the estimates of the CaII emission layer altitude, arrived at in reference 3 ($h = 100$ km), and the altitudes at which the maximum of Mg^+ ion and Ca^+ ion concentrations are recorded ($h = 103.5$ km to 105 km).

If we adopt the meteor hypothesis of Ca^+ ion origin in the atmosphere (ref. 3), we should not be surprised at the detection of a greater amount of Mg^+ ions. Magnesium is the most abundant metal in stony meteorites, which as is known, predominate in meteor showers (ref. 8); its average is 16 percent of the weight. (Ref. 9.)

The closeness of the recorded ion-concentration ratio $\frac{n_{Mg^+}}{n_{Ca^+}} = 25 \pm 8$, in the given launching, to the ratio of the number of atoms of the same elements in meteorites $\frac{n_{Mg}}{n_{Ca}} = 15$ should be noted particularly (ref. 9). This circumstance may be explained by the fact that the ionization of fast-flying evaporated Mg and Ca atoms must take place in an identical fashion, at their interaction with atmosphere molecules, and the same goes for the recombination of formed Mg^+ and Ca^+ ions. Because of the resemblance of the physicochemical properties of these metals, the constants of the processes of ionization and recombination must be close.

The possibility of an outright detection, during periods of diurnal meteor-shower activity, of considerable quantities of magnesium and calcium ions, located in a comparatively thin layer, is in itself a feat of great interest. The same can be said of quantitative relationships and values of these ion concentrations. All this corroborates the hypothesis of their meteoric origin.

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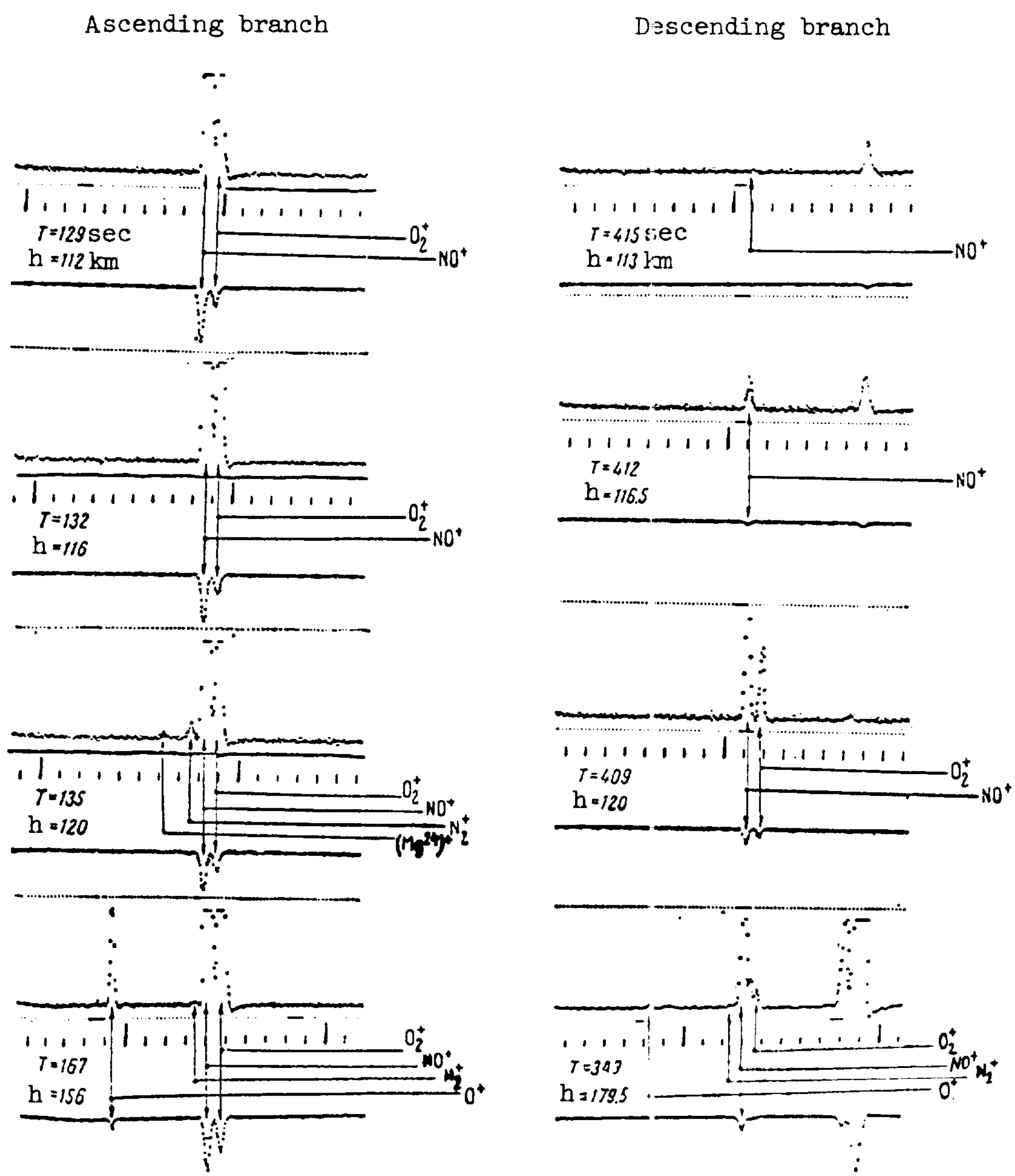

Figure 1.- Concluded.

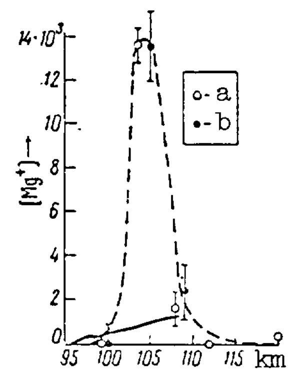

Figure 2.- Variation of magnesium-ion concentration in the atmosphere as a function of the altitude. a is the variation on the ascending branch of the trajectory, and b is the variation on the descending branch. The dotted line represents the possible profile of the Mg^+ ion layer.